FlexTech Alliance Quarterly Workshop
"Transparent Conductors"
& Tour of Cambrios Technologies
Date: August 17-18, 2011

Agenda

Wednesday – August 17, 2011

Tour:

Location: Cambrios Technologies
Address: 930 East Arques Avenue, Sunnyvale, CA 94085

3:30 – 4:00 PM	**Check in/badge pick-up @ registration desk in Cambrios Lobby**
4:00 – 5:00 PM	Tour of facility

BREAK / DRIVE TIME

Networking Cocktails & Dinner :

Location: Pedro's Restaurant
Address: 3935 Freedom Circle, Santa Clara, CA 95054

5:30 -6:30 PM	Networking - No Host Cocktails
6:30 PM – 8:00 PM	No Host Dinner at Pedro's Restaurant

Thursday – August 18, 2011

Morning - General Session:

7:45 - 8:00 AM	**Registration / Continental Breakfast**
8:00 – 12:20 AM	Speaker Presentations
12:20 – 1:25 PM	**LUNCH**

Afternoon - Panel Discussion

1:25 – 2:55 PM	Panel Discussion

What is the roadmap to device performance for the next 1 to 5 years?
Which TC alternatives are best suited for which applications?
What new applications will be enabled by advances in TC alternatives?

Luncheon Sponsor

FlexTech Alliance Quarterly Workshop
"Transparent Conductors"
Thursday Agenda

Thursday – August 18, 2011

Morning - General Session:

7:45 - 8:00 AM	**Continental Breakfast**	
8:00 – 8:15 AM	Welcome & Introductions	Stacy Oresman, FlexTech Alliance
8:15 – 9:00 AM	KEYNOTE "Development and Application of PEDOT Films"	Debasis Majumdar, Kodak
9:00 – 9:25 AM	"Real World Opportunities for Alternative Transparent Conductors"	Lawrence Gasman, NanoMarkets
9:25 – 9:50 AM	"Transparent contacts for photovoltaics"	Maikel van Hest, NREL
9:50 – 10:15 AM	**BREAK**	
10:15 – 10:40 AM	"Solution Processed Metal Nanowire Transparent Conductors"	Rahul Gupta, Cambrios Technologies, Inc.
10:40 – 11:05 AM	"Carbon Nanotube Applications . . . Gaining Traction?"	Robert F. Praino, Jr., Chasm Technologies, Inc.
11:05 – 11:30 AM	"Mesh transparent conductors: orthogonal and random array technologies"	William J. Ray, Nth Degree Technologies Worldwide, Inc.
11:30 – 11:55 AM	"Transparent Conductors in Organic Photovoltaics"	Zheng Xu, Solarmer Energy, Inc.
11:55 – 12:20 PM	"Novel Materials for Touchscreens"	Bob Mackey, Synaptics, Inc.
12:20 – 1:25 PM	**LUNCH**	

Afternoon - Panel Discussion

1:25 – 2:40 PM	Panel Discussion and Session Review	ALL SPEAKERS PARTICIPATE
2:40 – 2:55 PM	Next Steps & Close	Stacy Oresman, FlexTech Alliance

Topics for the panel:
What is the roadmap to device performance for the next 1 to 5 years?
Which TC alternatives are best suited for which applications?
What new applications will be enabled by advances in TC alternatives?

FlexTech Alliance Transparent Conductor Workshop

Summary by Harry Zervos, IDTech Ex

The workshop was attended by about 60 people active in the printed electronics industry and keen on finding out developments on transparent conductor solutions beyond ITO.

The workshop's keynote was delivered by Debasis Majumdar with Eastman Kodak, focusing on the development and applications of PEDOT films (earliest work as far back as 1947!), which find an opportunity in applications that require increased flexibility or stability in conductivity under strain, with an aim of a 25-40% reduction in price when compared to similar grade ITO.

Taking into account the variability in performance of commercial grade ITO, an observation emerged that there are cases where PEDOT performance, in terms of transmission and resistivity, is equal to ITO.

Today's state of the art PEDOT (Clevios PH 1000) has reached 300 ohms/sq. at 95.9% bulk transmission or 91.2% transmission on 4mm thick PET which allows it to be comparable with ITO in the range of conductivity between 100 and 300 Ohms/sq. (For lower resistivities, ITO outperforms PEDOT)

Display applications identified by Eastman Kodak include resistive touchscreens, polymer dispersed liquid crystal displays (PDLC) or semiconductive coatings on electrodes for PDLCs. It's interesting to note that in the resistive touchscreen applications, a wash of SWCNTs deposited on top of PEDOT gave a great improvement in the number of cycles the touchscreen could withstand, with no change in the achieved conductivity levels.

Laurence Gasman of NanoMarkets focused on the markets for transparent conductors, with the display market taking up the largest share by far, and ITO being the main material (difficult to displace, old ways die hard and ITO tends to have optimal combination of conductivity and transmission.

It's interesting to note though that the PV market has moved away from ITO: a-Si manufacturers for example use ITO, FTO and AZO, First Solar is using FTO and most CIGS PV manufacturers use AZO. 2010 and 2011 has seen a rapidly growing interest in ITO alternatives, with touch displays being the most targeted (the boogie board by KENT Displays being an interesting example of a device using PEDOT:PSS). But according to NanoMarkets, transparent conductors based on carbon nanotubes and nanosilver are also expected to see strong growth while graphene seems to be a bit further behind in terms of taking up market share as it's still difficult to get hold of substantial quantities of the material.

Maikel van Hest with the NREL listed the main issues of conventional TCOs for photovoltaics:

- ITO: Expensive
- FTO: High temperature deposition
- AZO: Poor Acid Resistance

Amorphous TCOs might be an alternative, amorphous Indium Oxide or Indium Zinc Oxide (which is also water and water vapour resistant) for instance. But the main question remains: is indium necessary for high conductivity and what are the alternatives to indium? a-CdSnO is highly conductive and indium free but unfortunately contains cadmium (which is not a big issue when used in CdTe solar cells that already contain it, although, sequestered or not, some markets do not allow Cd-containing products, e.g. Japan).

Rahul Gupta, Director of business development with Cambrios Technologies focused on the nano-silver based approach that the company's working on. The main market focus for Cambrios is the strong growth area of projected capacitive touchscreen technologies (typically 100-250 Ohms/sq.), with a secondary focus on the displays and PV market (<10-100 Ohms/sq.). Companies like Hitachi and Toray have already announced film products using Cambrios' materials

An important advantage is the ability to process Cambrios' ClearOhm™ at low temperature without losing performance, which allows for the use of plastic substrates such as PET (remaining over 90% transmission when reaching down to 20 Ohms/Sq. sheet resistance whilst achieving lower reflectance and more neutral colour than ITO).

In terms of patterning, photo patterning, screen printable etchants, laser or direct patterning are all compatible with the material allowing for versatility in processing and hence, the ability to tune processing requirements of the final component.

Working with Nissha (touch sensor) and Synaptics (touch module) on the development of touchscreens, smart phones incorporating ClearOhm™ were first made available in early 2011. Cambrios is also working with Plextronics in the development of OLEDs using the materials developed by the two companies, leading to 30% higher efficiency and lifetimes similar to those achieved with ITO. Cambrios is also working with Ascent Solar on CIGS solar cells achieving efficiencies similar to ITO cells.

Bob Praino with Chasm Technologies focused on the use of carbon nanotubes and their use in transparent conductor applications with the company working with SWeNT and targeting resistivities of about 100 Ohms/sq.

William Ray with NthDegree Technologies talked about Cartesian and non-regular transparent conductor arrays, demonstrating some very interesting lighting elements utilizing networks of silver nanowires.

In more device-centric presentations, Solarmer discussed their needs to drop their cost structure down (currently at about $6/Watt) with conductive electrodes and encapsulation being the highest costs in the material breakdown hence, having a big interest in ITO substitution but ITO is still giving best performance in terms of efficiency, when compared to PEDOT or PEDOT with metal grids.

Finally Synaptics discussed the need for novel transparent conductors for the touchscreen market, especially for projected capacitive. Bob Mackey did point out though that ITO is not really that expensive if one takes into account its performance levels and the invisibility of patterns when used with good index matching.

An important issue that arose from the workshop is the ability to come up with a specific cost of ITO films, as it's difficult to estimate its contribution to the overall cost structure of devices and of course the fact that lower cost solutions are not necessarily attractive since, performance levels need to be reached for many applications that are a prerequisite in order to displace the use of ITO.

Transparent Conductors Workshop - Panel Discussion Summary by Denise Rael

The key take away from the panel discussion was that existing products such as LCDs are not likely to start using TC alternatives. The retooling costs are too expensive and the risk too high. New products and technologies , such as OLED and OPV, may be able to use alternatives because there is no incumbent process.

Q . Why would you need a flexible display?

A. Flexible displays are portable, ultra high definition. A large screen fold down can be used in the home or in the field for soldiers. The market is smaller than that for cell phones.

Q. Is the only problem the TCO?

A. There are other problems such as metal backplanes, TFT, and power supply among others.

Q. What about dots?

A. E-paper makes for a great piece of paper but not a display.

Q. What are the pros and cons of On Cell vs. In Cell

A. Must use ITO, fails when it is strained 1%. There are process related issues as well. Make the display, then cut the glass down. On cell is not that easy to integrate. In cell seems more reasonable to do. There is high capacitance with in cell.

Q. Touch vs., transparent conductor. Will one convention take all?

A.

Silver nanowire has a head start.

ITO is the incumbent. It's reasonably good, it works and it's scratch resistant. ITO on glass is good; on PET it is vulnerable.

Patterning needs to change.

Nanowires are competing with photoresist costs.

Opportunities exist for coating. Need a 30 -40 % reduction in patterning. The cost of change is too expensive. Additive is the way to go.

IZO story: Samsung got interested; thought 30% would be using. The reality is 3%.

Q. What is the driver to move away – is it cost?

A:

If there is nothing to replace it, cost won't matter

Indium used to be artificially cheap, the price has skyrocketed with demand

Cost and performance – change is driven by new functionality, it needs to be printable

Cost less in Gen 8 than Gen 4 or Gen 2

R&D to pilot production multi year, will happen for certain applications

PEDOT not always TC, used as hole injection also, using PEDOT where needed may be 1st step in using it elsewhere

Yes, needs to be a comfort level, pay off will be big for someone who makes it happen

Q: I production likely to be in web form?

A:

Displays half R2R half sheet feed

In OLED possible for web to become incumbent because no one is in high production yet (as opposed to LCD)

Cutting depends on feature size, evaluation of roll needs to be considered, pre-patterned is a different story

Biggest problem is testing

Q: How much ITO is currently patterned?

A:

a-Si is patterned

For OPV patterning is an important process, some companies have capacity for their R2R and would like to use their equipment. It's a case by case basis for OPV.

Choice is related to volume, economies of scale for roll feed

Q: Is most cost from patterning?

A:

if you can print, will replace ITO but depends on application, fine features cannot use screen printing

You can build smart substrate, If printing material is larger than feature you are printing – pattern the substrate

Q: Is sputtering the only process for ITO

All: yes

Q: In the next 5 years – what products will be on the market with alternative TC?

A:

Membrane switches

Touch panels, flexible displays, possible OLED lighting

Displays, photovoltaics (not in next 5 years)

Better chance with PV because new product/process there is an openness to alternative technology

Display, OLED because they are large area, OPV if reasonable cost

Membrane switches, simple devices due to yield challenges, portion of touch panels, PV

5 years incumbent still ITO, silver nano, carbon nanotubes, extremely flexible and tough touch

OLED lighting to OPV, most open to new technology